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ABSTRACT

This in-depth review of the literature synthesizes articles and abstracts identified as education-oriented microcomputer research studies published since 1979. A brief, historic overview of educational computing is followed by a review of the Becker (1983) survey, which concerned the distribution of microcomputers in education in the United States, and of several other survey studies that provide a framework for viewing the research. Differences in research using microcomputers and main frame computers are outlined. Case studies and reports suggest the types of microcomputing efforts that are representative of the major areas of emphasis in instructional microcomputing. Specific research studies on microcomputers are then grouped by the following content areas: general learning, computer literacy, mathematics, music, reading, science, and typing; a summary is provided for each content area. Conclusions based on the research reviewed indicate that instructional microcomputing can be a valuable educational tool; that affective factors such as motivation and self-esteem are enhanced through the inclusion of microcomputers in an instructional setting; and the use of instructional microcomputing is most effective as an adjunct to traditional instructional methods. A 12-page bibliography is included. (LMM)

THE EFFECTIVENESS OF MICROCOMPUTERS IN EDUCATION

by

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INTRODUCTION

The subject of instructional microcomputing is a timely issue. A variety of alternative instructional strategies have been suggested to facilitate the incorporation of the microcomputer into the classroom setting. However, at the present time, little definitive research has been published concerning the effectiveness of this potentially innovative educational technology. The articles in this report have been reviewed by the author and are believed to be accurately synthesized. Unlike a significant portion of what is written concerning microcomputers in education, this report is intended to convey the information provided by researchers. It is intended to be written in a form and with a measure of detail such that interested educators will be provided sufficient information upon which to base instructional microcomputing recommendations and decisions.

PROCEDURE FOR THE REPORT

This report represents an indepth search of the literature for article titles and abstracts believed to be

informative surveys and research studies concerning the field of microcomputers in education. More than twelve hundred article titles and abstracts were identified for potential inclusion in the report. The articles were judged concerning the percieved probability of the article being a microcomputer research study. Following the judging, the remaining research articles were obtained for purposes of in depth review. Each article was read to determine the extent to which it met the criteria of being an education oriented microcomputer research study. All articles found in the literature which were judged as meeting this criteria have been included in this report. The remaining articles were carefully synthesized. The articles were grouped according to content area. A few surveys and case studies were included for purposes of illustration and general interest. Finally, summary paragraphs were prepared for the articles in content areas which include more than one research study. The bibliography included with this report is composed of all of the articles which were obtained for purposes of closer scrutiny. Perhaps others will find the references useful as an initial screening for other research areas. Few articles having a publication date earlier than 1980 were considered for reasons covered elsewhere in this report. Undoubtedly, there are articles which have been excluded from closer scrutiny due to the lack of perception

on the part of this author. For those instances of omission, this author offers a sincere apology to the author or authors. Most certainly, a follow-up work will be forthcomming; therefore, any omissions will be rectified in subsequent editions.

OVERVIEW

A number of studies have been published which discuss CAI or computer assisted instruction (Chambers and Sprecher, 1980; Burns and Bozeman, 1981; Forman, 1982; Hopmeier, 1981; Jones, 1981; Kearsley, Hunter and Seidel, 1983, Marsh, 1983). Trends in this country and abroad have been outlined and compared to a variety of instructional and educational approaches. Measurement instruments have been developed to attempt to demonstrate the value of CAI. The variety of definitions for CAI have suggested that perhaps no one can agree and, yet, almost "everyone" knows what it is. The term CAI has been used to refer to everything from Pavlovian-Skinnerian conditioning to the most elaborate schemes which loosely associate people with a mechanical device in an environment where "assisting instruction" is questionable, at best. By default, CAI has become an all encompassing term just as computer oriented instruction and instructional computing.

There are a number of terms found in the literature which require some clarification regarding their typical use. However, it is should be recognized that in practice and in the literature, the differences in definitions may become inconsequential. Computer based education (CBE), though seldom used, is also understood to be an all encompassing term. The thrust of CBE focuses upon learning or education as opposed to instruction. In contrast, the emphasis of CAI is on the presentation while CBE is outcome oriented. Additionally, CBE is usually associated with a curriculum in which a computer program can be identified to function as being essential to the foundation of the educational process. Computer based instruction (CBI) usually refers to situations which, at the very least, demonstrate teaching which relies upon a computer program. This term shares the foundation attribute of CBE and the presentation feature of CAI. That is, CBI requires that the presentation rather than the learning have a computer program foundation. Computer based teaching (CBT) is very rarely found in the literature. For all practical purposes, there is no difference between CBI and CBT other than the connotational differences between the terms instruction and teaching. Closely allied with these terms is computer assisted learning (CAL). This term bases the outcome on a performance by the subject. By definition, learning

suggests that a measured change in the subject behavior is expected. Thus, a CAL computer program is expected to assist the subject in demonstrating a measurable change in behavior. Computer integrated instruction (CII) very rarely appears in the literature. The term CII refers to any situation in which the computer is involved in the instructional process. In CII, the machine could be used as a paper weight to which occasional reference is made. More likely, the machine is used as a demonstration tool. Overhead integrated instruction or chalk-board integrated instruction are analogous terms. CII is, quite possibly, deserving of more use since CII more accurately describes what the survey studies suggest must be the situation in many schools. Computer managed instruction (CMI) is a relatively recently coined phrase which refers to the handling of an instructional setting. Typically, the use of CMI is concerned with record keeping from an instructional view point. Many administrative functions which have been assigned to computer programs are now being revived under the umbrella of CMI. As it is generally used, CMI is concerned with all aspects of management in an instructional setting. Thus, any sequencing or record keeping that is accomplished, at least in part, by a computer program can be referred to as CMI.

Computing devices are available in a wide variety of shapes, sizes, configurations, and other descriptive adjectives. All of these attributes continue to explode exponentially as the demand and the technological advances race with the speed of light toward a yet to be determined level of sophistication. As a result, much of the research has been accomplished on hopelessly obsolete devices. Many of the programming techniques and programmers have been shelved as irreconcilably out-of-date.

It is generally accepted that the technological breakthrough which is responsible for current microcomputers occurred during the early 1970's. The event centered around Dr. Ted Hoff, of Intel Corporation, whose insight is credited with successfully producing a microelectric circuit on a silicon chip. A small electronics firm by the name of MITS, in Albuquerque, New Mexico, is usually credited with the release of the first microcomputer kit in 1975 called the Altair 8800. During 1977, Commodore Business Machines released a personal computer, followed late in the year by Apple and Radio Shack. These small computing devices, which took advantage of microelectronic technology, were appropriately referred to as microcomputers.

It is important to recognize that by the end of the 1977-78 school year, microcomputers had only begun to be advertised and marketed. By the beginning of the 1978-79

school year few educational institutions had obtained microcomputers. This period neared the end of the 1978 calendar year. Instructional microcomputing had not been well accepted, except for vocational programs whose goal was to instruct students in the content area of microprocessor electronics. By the end of the 1978-79 school year, in mid-1979, researchers had only begun to respond to the demand for information concerning instructional microcomputing.

As a result of this abbreviated historical overview, this report on instructional microcomputing is restricted to including articles with dates more recent than 1979. It is highly unlikely that timely research in the area of instructional microcomputing was accomplished prior to the 1979-1980 school year. Further, evidence of this was presented in a national survey (Becker, 1983) which determined that by period of July, 1980 to June, 1981, 6% of the elementary schools and 38% of the secondary schools had obtained at least one microcomputer. Again, it is suggested that very few research studies concerning instructional microcomputing could have been conducted, analyzed and reach publication prior to 1980.

SURVEY STUDIES

The Becker (1983) study is ostensibly the most comprehensive and timely survey conducted concerning the distribution of microcomputers in education in the United States. The study reports the findings, identifies the assumptions and makes inferences which are supported by the data. Researchers and research articles of this caliber are rare. Anyone having an interest in the distribution of microcomputers in educational institutions in the United States would be well advised to obtain a copy of the Becker study. Only part of the study has been published as of the date of this report; however, it is available in a continuing newsletter format.

The Becker study is based upon a sample of 2,209 schools in the United States from which a 96% return rate of the questionnaire was obtained. The researchers were able to obtain this unusually high rate of return through telephone follow-up contact. Both parochial, private and public institutions were contacted at the elementary through high school levels. The study reports on data for the period beginning in Ju 1980 and ending in January, 1983. The study suggests that the use of microcomputers in the schools, though widespread, is not as pervasive as has been suggested by some.

Although somewhat irregular, this author has chosen to quote directly from the Becker study instead of attempting a synthesis. The findings of the study are extensive and of a nature such that graphs and involved explanations would be required. Further, the Becker study is sufficiently understandably written so as to require little editorializing. The following three paragraphs are taken directly from the Becker study and are believed to be an excellent summary of the typical use of microcomputers as determined by this national survey study.

"I: Micro-Owning Elementary Schools

The typical microcomputer-owning elementary school has two microcomputers, each used for about 11 hours per week, or a total of 22 hours of use per week by students under the direction of a teacher or other staff member. About 62 students (in the student body of 400) share these 22 hours of use, which is equivalent to about 20 minutes per user per week.

If computer time at this 'typical' school were divided among activities according to the average or mean use of student instructional time (as we estimate it from reported and imputed use in elementary schools), we would find the following distribution of uses: Approximately 40% of all instructional time on the microcomputer is spent by having students use computer programs for practicing math and language facts, spelling drills, and various other memorization tasks. Approximately one-third of the instructional time on the microcomputer is spent having students copy, write, and test computer programs. Students spend most of the rest of the time (about 20% in all) playing games under the direction or approval of the teacher. Many of these are 'learning' games, presumably designed to be 'drill-and-practice' assignments presented in a more entertaining, and presumably more motivating, guise.

12

II: Micro-Owning Secondary Schools

The typical microcomputer-owning secondary school has approximately five microcomputers, each in use for 13 hours per week, or a total of 65 hours of use. About 80 students (in a student body of 700) use the equipment in an average week--a little more than 45 minutes per user. Programming and computer literacy activities occupy fully two-thirds of the instructional time on computers in secondary schools. 'Drill-and-practice' activities take up another 18% and the remainder is split among 'learning games,' various advanced applications such as word processing, science lab work, and business courses, and other activities."

The Becker (1983) study provides a basis upon which to build an understanding of the microcomputer research. It is obvious from the study that most students have very little opportunity to spend time using the microcomputer. Therefore, many research studies probably have been conducted in special environments with unusually high ratios of students to microcomputers. Those schools in which studies have been conducted, by definition, are special cases. Thus, the research should be closely scrutinized for

instances of assumptions which would undermine the generalizability of the results. This does not suggest that the studies are not valuable. On the contrary, any well done study serves to provide information concerning the effective use of this new technology. In attempting to apply the results of research studies, care must be taken to maintain an environment which is similar to the environment in which the research was conducted. Studies which have been demonstrated to be successful on microcomputers may result in significantly different results when essential differences are overlooked. The point is that, due to the numbers of subjects required for statistical significance, research outcomes may apply only in specific situations. A particular school learning environment may not be afforded the luxury of student to microcomputer ratios comparable to those of the research studies. The Becker study serves to illuminate the incidence of microcomputers and thus serves as a stage for discussing current research concerning microcomputers.

A survey, **"Software: Topics & Types,"** (1983) was also conducted in an effort to discover distribution frequencies for a variety of categories of software. Unfortunately, the sources were identified as "...major publishers of educational software," since it would be informative to know which publishers were polled. The study attempts to provide

some insight into an area in which "almost everyone" has relatively accurate preconceived notions. The two content areas in which software is produced at the elementary school level were identified by the study to be language arts and math. The three areas which were identified at the secondary school level are math, language arts and science. This categorization appears to be somewhat limited since it lacks areas such as geography and history. Further, the number of word processing programs on the market today would be expected to account for, at least, a small percentage. Thus, the comprehensiveness of the survey of "major publishers" is considered suspect.

The results of the survey indicate that the majority of math software available at the elementary school level is in arithmetic (90%). Language arts, on the other hand, appears to be relatively evenly distributed among reading (25.1%), spelling (20.7%), and grammar (17.7%). The remaining third is distributed among vocabulary, reading preparation, punctuation, phonics and others. At the secondary school level, math is again primarily arithmetic (35%) but algebra (32.4%) is almost as prevalent. The remainder consists of metrics, geometry, calculus, and others. Language arts consists of vocabulary (36.6%), grammar (19.7%), and reading (15.4%). The remaining content areas include, among others, writing, spelling, and punctuation. Concerning science

software, the content areas of physics (27.4%), biology (21.2%) and chemistry (21.2%) dominate. Areas such as ecology, general science and geology are also represented.

The results of this survey study are not necessarily surprising. The survey procedure of the study casts a measure of doubt on the comprehensiveness of the results. The survey does suggest that microcomputer studies are conducted mostly in these content because software is readily available.

Brief mention of one final survey (**Kulik, Bangert** and **Williams, 1983**) which appears regularly in the literature is appropriate. This survey identified 51 studies concerning "computer-based teaching" and reported the results in the form of a meta-ana[illegible]s. The study determined that gains could be expected in final examination scores and follow-up examination scores. Positive attitudes could be expected toward computers and toward the course in which the computer was used. The total amount of time needed by the students to learn can be expected to be reduced. All of these findings are as compared to control groups and apply to the mean difference between the groups.

This study is of particular interest here because the Kulik study is referenced often concerning microcomputers. However, the Kulik study was not an evaluation of

microcomputer research. All of the studies included in the Kulik study were published during or prior to 1979.

MICROCOMPUTER RESEARCH

It is important to recognize that differences exist between research on mainframe computers and research on microcomputers. The major differences involve three areas of concern. First, the general impressions of the subjects toward the visible equipment and surroundings differs between mainframe computer studies and microcomputer studies. Second, certain features of mainframe operating systems necessitate recognizable differences in performance of instructional computing programs. And third, the timeliness of the programming and instructional tactics differs between previous mainframe instructional computing and current instructional microcomputing.

First, the general impressions of the subject differ concerning mainframe monitors and microcomputer monitors. The physical arrangements associated with mainframe units differ from microcomputers. The subject's awareness of these subtleties most assuredly has an effect on research results. None of the reviewed studies report attempting to conceal the identity of the computer system in use.

Subjects are made aware of the equipment being used by seeing the name of the equipment. The presence or absence of mass storage devices indicates the nature of the equipment. Few mainframe computers have portable tape recording devices placed in the immediate vicinity of the terminal. Floppy disk drive units are rarely associated with mainframe terminals. The few studies that report using "naive subjects," may have a tenuous defense concerning this issue. However, the physical location of the equipment may well undermine the arguments which use naive subjects as a defense. Mainframe units are not well known for their transportability. As a result, the subjects must be taken to another location for testing. The issue of remote terminals will be dealt with subsequently. Microcomputer units may be transported into the environment of the subject. Naive subjects can hardly be oblivious to the differences. Thus, it is argued that the general impressions developed by the subjects differs in mainframe environments as compared to microcomputer environments. It is believed that this alone differentiates research on mainframe computers from microcomputers.

The second area of concern involves a somewhat technical aspect of the mainframe computers and microcomputers. Hopefully, the explanation which follows will be understandable and relatively free from the usual

"mumbo-jumbo" jargon associated with the subject. Mainframe operating systems use a number of tactics which are designed to make using the machine more cost-efficient. The philosophy among mainframe operating systems programmers is that the machine should be computing all of the time. "All of the time," means every portion of every second. As a result, the program which is in control of the operation of the mainframe computer is designed to allow many users to take advantage of computer "simultaneously." The illusion of simultaneity is created by accepting input from one user while another user is thinking. At computer speeds, users can be "sandwiched" literally between the keystrokes of even the fastest typists. The exact arrangements which permit this to happen are beyond the realm of the current discussion; however, suffice it to comment that many users are accessing the memory of the mainframe in a very short time period. The tactics used allow any given program to take advantage of only a small portion of the memory of the mainframe computer. This means that large programs are not in the machine in their entirety at any one time. Further, when a number of people attempt to use the machine, time lags begin to become obvious to the user in the form of pauses between inputing and receiving a response. This is caused, in part, by the machine having to find the portion of the program, input the users information, and send the

reply back. All of this occurs during the time many others are doing the same thing. Microcomputers do not suffer from this problem. The memory of the microcomputer is specifically for the use of one person. Programs can be written which are in the memory and ready for access without delay. In fact, the available user memory space for some mainframe computers is smaller than that of microcomputers currently on the market today. Microcomputer programs are typically written with little regard for paging and interrupts, or any of the concerns of the multiplexing or multiprogramming requirements of mainframe systems.

Mainframe terminals are either hardwired direct or use the telephone system to connect to the mainframe computer. Most mainframe computer systems have a limited number of hardwired access lines. As a result, the number of hardwired terminals available for instructional computing research is limited. Telephone or dial-up lines are usually restricted regarding the speed with which information can be transmitted between the terminal and the mainframe computer. These dial-up terminals are also restricted concerning the screen formatting capabilities of clearing the screen and creative formatting of the screen space.

The proceding has been explained in order to present the following. The typical instructional microcomputer program executes from beginning to end without accessing the

mass storage device. The size of microcomputers permit the program to operate at microcomputer speeds without loading more program from the tape recorder or the floppy disk drive. The microcomputer program does not have to wait for another computer to send information to the mainframe computer. Typically, the microcomputer is capable of responding without mainframe computer throughput delays. Microcomputer displays are limited primarily by the creativity of the programmer. Partial screens may be filled in, random display locations may be accessed and reverse scrolling employed. All of these tactics are readily available to the microcomputer programmer. Therefore, it is argued that the control of variability and display speed can differ significantly between microcomputers and mainframe computer terminals.

The third area of concern involves the timeliness of research concerning computers. This is an important consideration for distinguishing between research on mainframe computers and research on microcomputers. The tactics of programmed learning and programmed instruction dominated instructional computing and research during the late 1960's and 1970's. The research information gained during that period was certainly valuable and has served to lay the foundation for today's work. Many of the individual researchers continue to remain active today. The names of

Alfred Bork and Patrick Suppes remain prominent today. However, the instructional microcomputing tactics available today differ significantly from those found in the earlier studies. Little resemblance exists between the 1970's programmed learning and the capability of current interactive microcomputer program simulations. The knowledge gained has naturally led to changes in approaches to instructional microcomputing. Successes or failures in those studies, though valuable, have as little resemblance to the results of today's instructional microcomputing research as Skinner boxes have on school classrooms. Basic explanations and understandings have historical and philosophical significance but are sufficiently removed from current capabilities as to suggest a logical division between research on mainframe computers and research on microcomputers.

Therefore, the research in this report has been restricted exclusively to microcomputers. As discussed in detail, the reasons involve the affect of the subject, the programmable capabilities of the display and the timeliness of research prior to the intrusion of the microcomputer. Subjects receive differential impressions from interactions with mainframe computer terminals than with microcomputers. The differences are a function of subtle cosmetic variations as well as basic differences of performance as a spin-off

from the requirements of a more complicated operating system. The differences in both equipment and approaches to instructional microcomputing has led to the decision to exclude studies prior to 1980.

REPORTS AND CASE STUDIES

Traditionally, case studies are viewed as anecdotal rather than as providing generalizable information. The nature of gathering data on a specific instance suggests that the effect of the treatment applies only to the particular subject. Case studies on microcomputers abound in the current literature and address a wide variety of issues (Grossnickle and Laird, 1981; Levin, 1982; Signer, 1983). Articles were reviewed on topics from "How you do..." through "How we did...," and more. Case studies concerning microcomputers tend to reflect more enthusiasm on the part of the writers than they do on the effect of the microcomputer. However, this abundance of interesting information and opinion is not without merit. This observation is most definitely a contributing factor to the requests for the publication of this report. Nevertheless, a few valuable case studies and reports have been found in

the literature. Some of the case studies are of such magnitude that the term "case study" hardly applies.

The Alaska (**Educational Telecommunications** for Alaska, Volume IV:**Individualized** Study by **Telecommunications**, 1982) study is reported here in rather lengthy detail. This study is very comprehensive and is presented here as a model for any microcomputer instructional program. Since the complete study is rather long, it is hoped that the synthesis which follows is of sufficient detail so as to serve as a valuable substitute. However, it would be well worth the expense and effort to obtain the complete report for any educational group contemplating the development of an extensive instructional microcomputing program. The approach used in the study appears to be very methodical and complete while never losing sight of the fact the human education is the goal. The reported thrust of the project concerns taking advantage of available technologies in an effort to overcome barriers to effective education. Although the barriers identified in the report are atypical, the process of seeking humanistic solutions through technology is to be applauded.

A survey of 2000 educators in Alaska was conducted to discover the areas and the extent to which the U.S. Department of Education should meet the needs of the educational system in Alaska. Of the 36 percent returned

surveys, 77 percent were from teachers and the remainder were from administrators and specialists. The researchers determined that the relative percentages of returned surveys closely approximated the relative populations found in the geographical areas of the state. Further, the survey was representative of the relative numbers of teachers and administrators in the system. In order to meet the identified needs, another survey was used to determine that a wide variety of telecommunications alternatives should be investigated. As a result of the two surveys, a two dimensional matrix emerged which served to clarify the alternatives. Administrative communications (1), resource identification and transmission (2), student diagnosis (3), classroom instructional support (4), and staff training and support (5) were identified as five areas of educational need. The five areas of educational needs which were identified could all be met by two telecommunications formats: (1) audio duplex or two-way telephone, and (2) computer information and data. In addition, the needs of classroom instructional support, and staff training and support could also be met by radio. Other, seemingly more creative alternatives, such as television with two-way audio, were determined to be too costly.

The study states that, "The educational needs are a direct outgrowth of problems associated with distance,

isolation, climate, and sparse population." It was determined that the alternative of telecommunications is a ready and relatively simple solution to the very complex educational problems which are unique to Alaska. The major concerns of administrative and instructional support, rapid access of information data bases, and bolstering limited rural instructional staff could be answered through the use of a telecommunications network.

Two major objectives of the program evolved concerning student performance. The issue of diagnostic testing of the students was addressed. Through discussion, it was determined that a planned diagnostic testing for grades 1-8 would realize little gain by using the computer telecommunications link. This testing was dropped in favor of later incorporation as a testing component in the 9-10th grades. The second major concern was to identify audio and computer oriented teaching strategies which were believed to be effective. Regarding the use of computers, a study by Dr. David Thomas, The University of Iowa, provided sufficient basis upon which to proceed. The authors report that the study by Dr. Thomas revealed that achievement gains could be realized by students who use computers. The study indicated that appropriate instructional aid might involve the content areas of biology, language arts, mathematics, reading, and production of typing materials. Simulations in

physics as an adjunct are valuable to student performance in content and problem solving; however, as a "...stand-alone CAI may not be (valuable)." Attitudinal studies found that motivation and interest may be enhanced but that measurable differences in study behaviors have not been detected. Student time requirements of CAI as compared to traditional measures have been found among high and medium ability students. The study determined that "...it appears that retention levels for students are comparable for CAI- and non-CAI-taught courses." Based upon the study by Dr. Thomas, it was agreed that the features of CAI serve to support the use of instructional computing and serve as an aid in overcomming the demographic and geographic obstacles of Alaska. Although not the subject of this discussion, the medium of broadcast audio and two-way audio instruction were found to be effective additions to the solution of the educational problems. Finally, the five components of the Individualized Study by Telecommunications were identified as (1) involving basic course materials, (2) the use of audio, (3) integrating CAI/CMI instruction, (4) using local supervising teachers, and (5) linking with the available master teachers. Initial testing of the audio equipment was successful and served to lay the groundwork for the delivery system.

The courseware for the program had to be developed for use within the constraints identified by the report on Individualized Study by Telecommunications. It was stated that a fortunate decision was made to build the entry level materials, and some elective courses, around existing correspondence courses. The majority of the work by the student on the computer took the form of multiple choice or fill-in; however, it was reported that some use of maps and time lines was made. Instructional materials used "help screens" and feedback; while, testing provided no feedback. In either case, the management option allowed the teacher to monitor the progress of students according to objectives.

Initial field testing of the program was conducted in three schools with 20 students from each school. The testing covered the first two week unit of "Alaska History" but, allowed three weeks time in consideration of the slower students. Reading comprehension tests permitted the selection of 10 students at each school to be above the mean and 10 students to be below the mean. Test site visitations were made to insure the correct operation of the equipment and to provide observations from which to make system revisions. A centrally located, one-day, intensive training program was held for instructional personnel. The results of the field testing indicate that there is some evidence to support the notion that too many repetitions can have a

depressing effect on achievement. Requiring students to correctly complete four repetitions of each question is suggested to have a detrimental effect on slower students only. Otherwise, students at all reading levels can be expected to perform without depressing posttest scores. Attitudes were reported to remain high concerning all aspects of the field test. It was mentioned that equipment failures is potentially the most crucial factor involved and must be eliminated in order to avoid the undermining of even the best instructional design.

The initial field test results suggested that a full-year pilot test should be carried out involving seven schools and over 120 students. Three day training sessions were conducted for supervisory personnel. Sites were selected, based primarily upon availability of telecommunications capabilities, small population, ethnic representation, and geographic distribution. Two site visits were completed by the project staff for the purpose of conducting interviews of participating site personnel and making observation of students working. The instruments used for evaluation included evaluation of training materials, student checklists, student pretests and posttests, cost analysis, and opinion surveys. Preliminary results suggest that the pilot study was a success. Significant student gains on achievement were realized in

"English" and the first semester of "Alaska History." The teachers attitudes were positive toward expanding the course offerings already in existence. Most students agreed (73%) that reading of the lessons was accomplished without teacher intervention. Approximately two-thirds of the students express a feeling of success concerning the program. Similar positive results were recorded with the "English" course and the "Alaska History" course.

The general evaluation of the instructional tactic used in the study was positive. Teachers view the students as needing to develop within themselves the skills to be "self-directed" in their approach to learning. Approximately 90% of the teachers reported that instruction was improved as a result of the program. The ability of the program to "...accommodate student differences." was cited as the reason for the outstanding success. The study reported that a student to microcomputer ratio of two students to one microcomputer was observed and considered appropriate. The authors were careful to note that a number of factors, including instructional design and space requirements, were instrumental in determining the ratio. All staff associated with the pilot testing program reported positive attitudes toward the program. It was noted that the staff reported that less of their time was required while using the instructional microcomputing program and

that this represented a change in attitude as compared with the mid-year evaluation. Student attitudes were positive since 80% of the students reported having enjoyed the microcomputer drills more than the traditional methods of instruction.

General Mathematics and Developmental Reading courses were developed in parallel with the pilot testing of "English" and "Alaska History." The pilot testing of these additional courses along with the existing "English" and "Alaska History" was accomplished with 25 schools. The students were randomly selected and most were of Native origin. The grade level was from 5 to 12 and the age range was from 10 to 20 years. The intent of this pilot study was to attend to more specific concerns of the level of effectiveness of the program. The Alaska Statewide Achievement Test (ASAT) and a content specific measure were used as a pretest for each student. The students were determined to be below the mean for the state. It was noted that considerable variability was in evidence. The authors report specific gain scores for each of the units of study; however, attempting to reproduce the results here would be overwhelming. However, significant gain scores were realized in the majority of the specific unit pretest versus posttest comparisons. The overall gain scores for the courses of "English," "Alaska History," "General

Mathematics," and "Developmental Reading" were all found to be significant. A few non-significant differences were reported as was a significant loss on one of the unit test scores in "English." The majority of the students (75%) preferred the microcomputer exercises, almost half (45%) ranked workbooks next, one-third (35%) placed teachers next and surprisingly, audio tapes (10%) and peer teaching (16%) were least liked. There is considerable evidence that student performance is increased through the use of audio tapes in conjunction with instructional microcomputing. Teacher attitudes were positive and teachers viewed the amount of work required to be less than that required of teachers in traditional courses.

In addition to these comments, the report historically details the four-and-one-half year project from initial planning work through the presentation of the results. Evaluation results and materials are included from both a formative and a summative viewpoint. Costs are carefully and completely described from initial purchase prices and ongoing costs to cost effectiveness. The authors carefully identify pitfalls, the tactics used to deal with the pitfalls, and suggestions for future projects which should serve to avoid problems. Specific recommendations are made concerning the content in this study as well projections and generalizations for other applications.

The remaining portion of this section highlights some of the many reports concerning ongoing uses of microcomputers. There are a large number of conference proceedings dealing with both computers and microcomputers. In addition, a large number of conferences have specific sessions for microcomputer presentations. Due to the difficulty of obtaining copies of these many presentations, only a representative sample has been included here. The bulk of the presentations of this type contain little substantive information concerning the effectiveness of instructional microcomputing. However, they do serve to suggest some of the alternatives which researchers could consider.

A document was produced which identifies numerous applications concerning the use of personal computers (Lavine, 1981). Many programs are discussed as being relevant to the selection of personal computers. Sources of information are provided for the potential purchaser to use to seek out additional information.

Another publication (Smith, 1982) contains a vast array of anecdotal accounts of the variety of uses for microcomputers. Categories such as teacher inservices, software standards, data transmission, control equipment, business education and administrative uses of the microcomputer are covered.

The conference proceedings on Microcomputers in K-12 Education (Barrette, 1982) discuss the variety of the uses of microcomputers in the K-12 range of educational applications. The uses of the microcomputers include applications in gifted programs, business education, administration, linkage between microcomputers and mainframe computing devices, language arts, elementary Title I reading programs, career awareness in K-8 and the writing and management of Individual Educational Profiles (IEP's). Again, the application of the programs serves to indicate both the range and the variety of the attempts to include the microcomputer technology into the instructional environment.

An anecdotal, case study at The University of Wisconsin (McIsaac, Bilow, Macrides, and Romstad, 1980) outlines a computer managed instruction (CMI) program (MICRO-CMI) which is designed to be used for grouping, diagnostics and prescription of student work. The paper identifies and discusses four reasons for implementing CMI on a microcomputer: cost, control, access, and convenience. Microcomputers are suggested to be relatively inexpensive and free from the many externally caused "down times" associated with mainframe systems. Many mainframe problems cannot be handled and are not under the immediate control of school personnel. Further, the user has immediate access to

the entire microcomputer system which often results in greater terminal display rates and the added convenience of being able to access the power of the computing machine easily during the normally heavily used, slow turn-around periods associated with mainframe systems. The authors note that a great deal of care was needed to provide for access to the data by the school personnel. The stated problem concerned the need to store large amounts of data on relatively small volume floppy diskettes which are usually associated with microcomputers. The resultant solution necessitated interchanging one of 37 data diskettes for access to student records in different content areas. The researchers report the use of a Digital Equipment Corporation (DEC) computer system which is a LSI-11 based system. The authors report this CMI system as being successful for managing instruction. The authors state that the use of "... small eight-bit computers is not recommended." Although the DEC system is often referred to as a minicomputer, the minimum requirement of this system, as indicated by the authors, is exceeded by commonly available microcomputers. Examples of these larger 16 bit systems are the Apple Lisa, IBM PC, and TRS-80 model 12, to mention only three of the more popular brands.

The proceedings of a search effort (IEEE Computer Society Press, 1981) describe the open competition fairs

which were held in the ten National Institute of Education regions for the purpose of identifying exemplary microcomputer programs. The intended subjects for the programs were targeted to be the handicapped. Programs in a range of areas were entered in the competition and ninety-five of the more noteworthy programs are described in the proceedings of the IEEE search. A total of five categories were represented with the number in each as follows: Hearing, Speech and Vision (25), Learning Disabilities and Mental Retardation (11), Movement, Neuromuscular and Neurological (27), Vision (24), and Non-specific (9). Although no data was reported regarding the effectiveness of the programs and little generalizability can be inferred, the relative numbers serve to provide a notion of the attention being given to the area.

The studies in this section require no unifying discussion, other than that which has already been included with the text. This section has been included to provide an indication of the types of meaningful instructional microcomputing efforts which have been found in the literature. Each of the citations have been well written and indicative of the effort dedicated educators have demonstrated in incorporating technological advances into the mainstream of education. It is further suggested that

these citations are representative of the major areas of thrust concerning instructional microcomputing.

RESEARCH

The remainder of this report will provide an indication of the research which has been found in the literature. A relatively large number of articles were reviewed from which the following studies were taken. Except as indicated, these studies are restricted to those which have been completed on microcomputers. The studies have been group by content areas. The topic area of General Learning appears to be an appropriate topic although it is not normally referred to as a content area. Typically these studies identify measurable learning tasks which are not necessarily traditional instructional content areas.

General Learning:

A dissertation study (Cox, 1980) sought to discover the problem solving ability among seventh and eighth grade students, ranging in age from 12 to 14 years of age. The

students were from a middle class community in the Detroit, Michigan metropolitan area. A total of 66 subjects were used in this study which consisted of 48 males and 18 females. The thrust of the study centered on the problem solving skills of collecting, organizing, analyzing, developing, and planning through the solution of a problem. The subjects in this study were randomly assigned to experimental and control groups. The experimental subjects were trained concerning problem solving through the use of a specially developed microcomputer program. Subsequently the subjects were availed the use of the microcomputer as an aid in the problem solving process. The subjects were given problems to solve in areas of life science, social studies, and environmental education. The problem solving sessions were designed to last approximately 50 minutes each. The study was designed to provide working sessions on each of three consecutive days or three consecutive weeks. The subjects were allowed to work alone, with a partner, or as a group of three or five students. The scores for the subjects on either the Differential Aptitude Test, the Cognitive Abilities Test, or the language portion of the Iowa test were used as an indicator of the randomness of the distribution of the subjects. Grade averages were collected for the subjects and together with the standardized test scores, served to indicate that an even distribution of

subjects had been identified. Interestingly enough, 64% of the subjects indicated that they had "...never interacted with a computer..." while 29% had played some games and 7% had done programming. The author reported that groups containing students of significantly different ability levels appeared to be overly discordant. The lower level students were usually erratic and became frustrated with the logical reasoning methods of the other students.

Although the quasi-correlational research design chosen for this study is not the most powerful of research designs, the results of the study are very useful and make a valuable contribution to instructional microcomputing. The anecdotal comparisons are useful because they were provided by trained observers with a controlled environment. The researchers report that the subjects remained interested in the problem solving activities. The more productive groups tended to remain in preset seating arrangements and internally insisted upon taking turns talking. The groups with a wide disparity of ability levels or age differences tended to be less productive. It was discovered that the time required to solve the first of the set of problems was significantly greater than the time required to reach solutions on subsequent problems. The data suggest that the training of the subjects resulted in a significant difference in the ability of the subjects to solve the problems. The subjects

in the weekly sessions more frequently tended to use the particular strategy which had been taught than did the subjects in the daily sessions. The researchers found that the larger groups were capable of arriving at a correct solution quicker than the smaller groups; however, the training appeared to have no significant effect on the time to reach a solution. It was concluded by the researcher that certain problem solving skills improve with time when using the microcomputer. The use of the training sessions on the microcomputer provided the subjects with the ability to organize data by using a matrix type problem solving technique very rapidly. Unfortunately, the methodology of using the matrix as an aid to problem solving may not be a most effective means for solving problems. The study does suggest that through the use of a microcomputer, behavior strategies can be effectively altered among seventh and eighth grade students. Interesting results occurred concerning group size. Although the groups of five students solved problems faster and more correctly, more "...social confrontation and friction..." occurred. Perhaps, interactions among early adolescents are being misinterpreted by researchers and school personnel. This study demonstrates that the larger, more disruptive groups were more productive; however, the production rate was not analyzed as a function of groups size. One might ask if the

five member groups were 40% faster than the three member groups since the group size is 40% larger.

Probably the most significant result of the study is that the microcomputer program was used to provide training for adolescent students and a measured behavior change was observed. The students having completed the single ten minute microcomputer delivered training module, quickly adopted the method. The data from the study suggest that the subjects continued to use the method taught throughout the study. In fact, the subjects having problem solving sessions which were a week apart used the method significantly more than the students having consecutive daily problem solving sessions. The implication is that the long term effects on the subject behavior is effective for the microcomputer training program. Apparently, the subjects having week long periods between the use of the training tactic were able to recall and apply the tactic. One might suggest that the shorter daily time between use of the tactic had the effect of interfering with the training on the microcomputer. This and the researchers comments suggest that less frequent use of the microcomputer may prove to be a more effective tactic.

One article (du Boulay and Howe, 1981) reports on two studies involving the use of LOGO. The first study consisted of 15 college level volunteers, was formative and

served to identify math deficiencies. The subjects learned LOGO; however, the results were mixed concerning attitude and math achievement. The second study involved 12 second year and 9 third year education students who were selected by the college of education staff as students in need of help in math with the concepts of shape and number. Randomly assigned experimental and control groups were established. The subjects were tested to determine attitudes and performance in math. The subjects were reported to have a dislike toward math and a like for teaching. After the study the attitudes and performance were in the same direction and to a greater extent. There were small but non-significant gains in math scores in all groups. One must therefore conclude that, based upon this study, the use of LOGO in this study has no effect on attitudes toward math and teaching nor does LOGO have an effect on math achievement scores.

Children and adults were used as subjects to compare learning approaches toward the computer programming language BASIC (**Hamada-Adler and White, 1982**). The study used 10 subjects from the college level and 10 subjects from the elementary school level, fourth and fifth grade. The adults were graduate level students attending a New York City private university and ranging in age from 23 to 40 years. The children were students from a New York City parochial

elementary school and ranging in age from 10 to 12 years. Although the subjects were reported to be from relatively affluent backgrounds, none of the subjects had any prior experience with a computer programming language and most had no prior experience with a microcomputer.

The purpose of the study was to observe and evaluate the performance of children and adults learning the computer programming language BASIC. As a measure of learning approach, the researchers chose to use verbal interaction between the subjects during the learning task. The authors cite research which supports the generally accepted belief that similar strategies are used by learners to solve problems. The differing rates observed among learners may be attributed to differing cognitive abilities and disciplines. It is argued that the observance of differences may not necessarily be a developmental function of age; rather, it may involve problem solving experience which is often associated with age.

The subjects used tutorial manuals in a self-paced mode. The manual used was an edited version which was designed to focus upon certain specific content. The text was read aloud for the subjects encountering reading level difficulties; however, the text was quoted verbatim. The 15 hours of video taped observation of the subjects was recorded and coded into five categories: questioning,

planning, monitoring, evaluating and non-computer related. In addition, the number of computer operations and errors were recorded for each subject. The inter-rater reliability was determined to be .88 for the verbal interactions and .96 for operations on the computer. A comparison was made to determine the effect of the novelty of the microcomputer situation by rating questioning interactions in a normal classroom. Although the attempt to establish reliability across settings was admirable, the use of a seventh grade class effectively undermines the generalizability.

The results of the study indicate that children and adults verbally interact similarly and make similar numbers of correct responses. As a result of the high reliability of the raters, a great deal of confidence may be placed in the results. Some interesting findings by the researchers include the observation that more negative comments were observed from the adults (7%) than from the children (2%). The vast majority of the subject's time was spent on task as evidence by the fact that less than 0.3% non-computer verbalizations were observed. The "computer output", as measured by the number of computer operations, by the adults was found to be significantly higher than that of the children (1.6 to 1.0). The authors suggest that results of this study support the current belief in the value of the microcomputer in an instructional setting. It was pointed

out that the tutorial manual used (Applesoft Tutorial) in this study is "...not self explanatory, and the role of the teacher is important when learning a computer language." This comment was evidenced by the fact that "...so many questions were directed to the examiner..." This study is interesting from the point of view of learning research because it is difficult to find a content area in which a sample of children and adults are equally naive. Certainly, further research in this content area can only lead to valuable discoveries concerning learning capabilities and styles.

Mainframe LOGO was taught to 22 boys ranging in age from 11 to 13 years having both above and below average ability in math (Howe and Ross, 1981). The subjects in the experimental group were transported to the university computing facility while the control group subjects remained in the regular classroom environment. Pretest math ability scores were obtained on all subjects. It was determined that the control group had significantly higher math scores on the pretest measure than did the experimental group ($p<.05$). Both the control group and the experimental group subjects improved in math achievement on the posttest as compared to the pretest scores ($p<.01$). There was no significant difference between the two groups on the posttest scores. Attitude measures indicated that the

subjects had high initial enthusiasm, distinctly less positive attitude mid-way through the experiment and relatively neutral attitudes at the end of the experiment. This was cited as evidence that the Hawthorne effect could be reasonably expected to have little or no influence on the achievement outcomes. The researchers conclude that the experimental treatment of using LOGO served to cause the achievement scores for the experimental group to increase and thus close the gap with the control group. That is, the use of LOGO served to move the experimental group scores from significantly worse to equal to the control group.

A study (Lewis, 1981) was conducted to investigate the relative interest of three and four year old students in LOGO programs. The subjects were attending a private preschool. They evaluated four procedures which were developed using the programming language "LOGO." The subjects were all identified as coming from upper-middle class homes, thus one might infer the ability level of the subjects. The author cites an article which suggests that minimizing keyboarding skill for young children and handicapped is a desirable goal. Based upon this article, the author suggests that activities written in the programming language LOGO are easier to use. The procedures which were designed for the children to use were titled "People," "Park," "Dallas" and "Build." The procedures

permitted the students to display and manipulate objects in relation to one another on the screen. The following short description of the procedures is believed to provide insight concerning the findings of the study. "People" provided a video screen for the students to assemble 20 parts to construct five human bodies. "Park" allows the students to manipulate cars and trucks. Garages may be displayed in which to park the vehicles until a total of 32 items are on the screen. "Build" permits the students to use squares to construct structures on the screen until a total of 32 items are on the screen. "Dallas" displays either a truck or an airplane on the screen for which the student chooses a variety of colors, speeds or directions.

The author reports that the subjects spent 1595 minutes over a total of 18 days being observed using the computer. Children were observed by recording the amount of time which they chose to use the microcomputer and the particular procedure chosen. The four year olds were observed to spend an average of 94.5 minutes per day on the microcomputer while the three year olds spent 79.4 minutes per day. It was reported that no difference was observed between the microcomputer use time of the group of four year olds and the group of three year olds. Unfortunately, no statistical comparison was reported; however, it is interesting to note that the use of "Dallas" was reported to occupy 48% of the

use by the students while the other three procedures combined accounted for only 52% of the use. Judging from the description given by the author, "Dallas" was significantly different from the other three procedures. "Dallas" required that the students manipulate the single object by speed, direction and color. This manipulative procedure apparently requires little on the part of the child while providing visual entertainment. It is suggested that the procedure is similar to moving a toy car along the floor. Each of the other three procedures required that the child create relationships among the objects. Once the relationships were created, the visual was static and provided no feedback for the operation of pressing the keys. That is, the response-feedback cycle of "Dallas" is ongoing while that of the other procedures reaches an end point after a specific number items is displayed. It is suggested that "Dallas" was the only procedure which the students could spend more time on.

A study was designed to determine the effects of learning a computer programming language, LOGO, on logical reasoning ability (Seidman, 1981). The subjects for the study were randomly selected from the 5th grade level, 10-11 years of age, of a public elementary school. The randomly selected group of 42 subjects was subsequently divided into an experimental and a control group. The experimental group

was taught LOGO on a PDP-11 minicomputer while the control group received no special instruction. The subjects were found to have no significant difference on any of the pretest measures. The subjects were found to have no significant difference between groups concerning performance on the same tests given as a posttest measure. Succinctly, the researchers were unable to detect any performance which could be attributed to the learning of LOGO among these subjects as measured by these standardized tests of achievement. The achievement measure used by these researchers were the vocabulary, comprehension, computation and concrete measures from the California Achievement Test. However, a repeated measures statistical analysis revealed that the control group posttest scores were significantly higher than their pretest scores for the reading total scores. And, both groups scored higher on the math computation and the math total scores considering the pretest as compared to the posttest.

The researchers have chosen to use the programming language LOGO since it is a "...LISP-like computer programming language with an English-like syntax..." and state that "Some claim that it (LOGO) can help children learn just about any formal subject." The researchers discuss the parallels between the semantics and syntax of LOGO, English and logical conditional statements.

Therefore, in addition to the achievement tests, the subjects were evaluated on principles of logic, such as "If p then q" assertions. The subjects were tested to determine their ability to assess the validity of the logical relationships. The subjects were also measured on their ability to assess the validity of biconditional logical relationships such as "If not p then not q." The several permutations of the logical conditional and biconditionals were investigated. The researchers were unable to determine any significant difference between the control group and the experimental group with the exception of one measure. The single exception was in the inversion principle when scored as a biconditional. For example, the statement "If p then q" is said to be stated in the inversion as "If not p then not q." This inversion assertion is considered to be a "fallacy" principle since it does not necessarily, by itself, lead to a valid conclusion. When the subjects were tested concerning this principle, the experimental group scored significantly better than the control group. The researchers argue that "...learning the LOGO branch statement correlates positively and significantly with the Inversion principle under the biconditional interpretation." It is significant to reiterate that the measurement of the Inversion principle under conditional evaluation and all other measures measures under conditional and biconditional

evaluation, failed to achieve significance. The authors suggest that the significance obtained is sufficiently specific to value the ability of students to learn this particular relationship through learning LOGO. However, they do state that there is no evidence in this study to suggest that the learning of LOGO, or any programming language, "... influences ones logical reasoning abilities." Therefore, this study does not support the assertion that the learning of LOGO will enhance ones ability to think logically.

Summary of the General Learning Studies:

Cox (1980) sought to discover the capability to solve problems, among seventh and eighth grade students. The study supports the opinion that through the use of a microcomputer, behavior strategies can be effectively altered. The more productive groups tended to remain in preset seating arrangements and internally insisted upon taking turns talking. The groups with wide disparity of ability levels or age differences tended to be less productive. The researchers found that the larger groups were capable of arriving at a correct solution quicker. It was concluded by the researcher that certain problem solving

skills improve with time when using the microcomputer. The students having completed the single 10 minute microcomputer delivered training module, quickly adopted the method. This research suggests that less frequent use of the microcomputer may prove to be a more effective tactic.

du Boulay and Howe (1981) reported on the use of LOGO involving 12 second and 9 third year education students. The subjects were reported to have a dislike toward math and a like for teaching. After the study the attitudes and performance were in the same direction and to a greater extent. There were small but non-significant gains in math scores in all groups. One must therefore conclude that, based upon this study, the use of LOGO had no effect on attitudes toward math and teaching nor on math achievement scores.

Hamada-Adler and White (1982) used 10 subjects from the college level and 10 subjects from the elementary school level (fourth and fifth grade) to compare learning approaches toward the computer programming language BASIC. The results of the study indicate that children and adults verbally interact similarly and make similar numbers of correct responses. The rearchers found that more negative comments were observed from the adults than from the children. The vast majority of the subjects time was spent

on task. The "computer output" by the adults was found to be significantly higher than that of the children.

Howe and Ross (1981) taught mainframe LOGO to 22 boys ranging in age from 11 to 13 years having both above and below average ability in math. Both the control group and the experimental group subjects improved on math achievement on the posttest as compared to the pretest scores. However, there was no significant difference between the two groups on the posttest scores.

Lewis (1981) conducted an investigation concerning the relative interest of three and four year old students in LOGO programs. The author suggests that activities written in the programming language LOGO are easier to use. It was reported that no difference was observed between the computer use time of the group of four year olds and the group of three year olds.

Seidman (1981) designed a study to determine the effects of learning LOGO on the logical reasoning ability of 42 randomly selected, 5th grade, elementary school students. The researchers were unable to determine any significant difference between the control group and the experimental group with the single exception of the inversion principle when scored as a biconditional.

Computer Literacy:

A study (**Johnson, Anderson, Hansen and Klassen** (1981) reports on an assessment of computer literacy and awareness. "The Minnesota research project was designed to (1) collect baseline data regarding pupil knowledge and understanding of computers, and (2) to determine the relative impact of various computing or computer-related activities in the schools on the development of computer knowledge and understanding." The research data for this study was collected during the period of 1977-1979. A total of 3,500 teachers were surveyed. The result was a set of 54 objectives in the cognitive domain. The objectives are representative of the areas of knowledge which teachers believed were indicative of computer literacy at that time. The areas of inclusion and the numbers of objectives in each area are as follows: Hardware (7), Programming and Algorithms (8), Software and Data Processing (13), Applications (10), and Impact (16). Additionally, Attitudes, Values and Motivation (9) were believed to be reflective of the affective domain. A test consisting of questions relating to an even distribution of 34 of the objectives was developed and determined to have a reliability coefficient of .90. From a sample of 1106 students in 51 classes, a total of 929 subjects were tested

in a pretest-posttest design. The subjects were given planned computing activities as an experimental treatment. The experimenters suggest that by providing "... various computing or computer-related activities..." the computer literacy of the subjects is increased as measured by the reliable Minnesota Educational Computing Consortium test. The study reported that all subjects increased in performance on the posttest over the pretest.

Mathematics:

One study investigates the contention that learning a computer programming language is an aid to understanding school mathematics (Hart, 1981). The author states that "... roughly 80% of the school population cannot cope with some relatively easy aspects of (algebra)..." The study uses 24 elementary level subjects doing 15 min. of hands-on work, once every 3 to 4 weeks. The programming language BASIC was used as vehicle to expose the subjects to assignment of variables and numeric values. Standardized tests were administered to the subjects. The first year subjects achievement gains on the tests were comparable to the achievement gains made by the third year math subjects. No control group was used; therefore, the gains cannot be

attributed to the treatment. The study does suggest that the use of a programming language to convey the assignment of values to variables and variable manipulation is a potentially interesting area for research. Intuitively, this rustic attempt identifies a fertile area for investigation.

Hyperactive children were studied (**Kleiman, Humphrey, and Lindsay, 1981**) to compare attention span on arithmetic problems using the microcomputer versus paper and pencil. The eighteen subjects ranged in age from 6 to 14 years and were attending a child development hospital clinic. The children were identified as hyperactive and determined to be suffering from abnormally short attention spans. The subjects were given difficulty level adjusted problems and told to "do as many problems as you want and stop when you think that you have done enough." The subjects used paper and pencil on alternating days with microcomputer program on the non-paper and pencil days. The authors state that the microcomputer program was designed to resemble the format of the paper and pencil activity as closely as possible. The problems for both presentation methods were generated by the same method to insure similar difficulty level.

The percentage of problems which were correctly worked by the students did not differ for the paper and pencil version as compared to the microcomputer version. Neither

the average time between each of the problems worked nor the average time to complete a problem differed between the two groups of subjects. However, the number of problems completed and the total time on task for the microcomputer group was double that of the paper and pencil group. That is, the hyperactive children demonstrated increased desire to work arithmetic problems on the microcomputer as compared to the paper and pencil. The authors state that the hyperactive children spent unusually long periods of time working on the microcomputer. The bonus is that no loss of accuracy or speed occurred when the subjects chose to work longer which in turn required longer attention span.

A pilot study was conducted (Moser and Carpenter, 1982) to investigate the transition phase as children learn to express verbal problems in symbolic written form. The informal learning strategies which are used initially by children begin are replaced as formal schooling instruction begins. The content area for this investigation is in addition and subtraction. The microcomputer was used to facilitate the process with a specially prepared program for 4 first grade students in a private school in Wisconsin. The microcomputer program was designed to permit the student to place boxes on the video display screen by pushing the right-arrow key. A total of 30 boxes may be depicted on the left half of the screen. By pressing the space bar, the

student may begin to display an additional number of boxes, up to 30, on the right half of the screen. Depressing the left-arrow key results in subtracting boxes from the screen and the space bar may be used as a toggle for switching between sides of the display screen. An audible "beep" is used to indicate to the student that either a maximum or a minimum limit has been reached (ie. less than zero boxes). In the case of no boxes, a number zero is display on the screen rather than using a blank screen. By using these keys, the student may use boxes to represent pictorially, numbers of objects which are described verbally. For example, "Tim has 12 candies." would be represented by 12 boxes on the screen. "He gave 5 candies to his sister." could be represented by a minus sign followed by 5 boxes. A series of 9 lessons were developed, each of which requires an average of 20 minutes to complete. The subjects were given both a paper and pencil, and a microcomputer posttest consisting of 6 problem tasks each. In the pretest screening, none of the subjects could correctly write "number sentences" as representations for problems at any level beyond the most rudimentary addition and subtraction. In the posttest measure, the four subjects could successfully write number sentences to solve problems. They could also use the computer to represent and solve a variety of problems. Although the training was on the

microcomputer, 3 of the 4 subjects were capable of writing symbolic number sentences which correctly depicted the word problems. The authors conclude that this pilot study suggests that first grade students can learn to use the microcomputer as an aid in representing problems in a formal way. The implication is that instructional tactics could be modified in order to permit the students to take advantage of "...children's natural ability to solve verbal problems..." in learning to translate the problem into a more formal algorithm.

Unlike many studies, one study (Steele, Battista, and Krockover, 1982) sought to investigate achievement in math skills among high ability students. The 30 subjects used in the study were identified as high intellectual ability students from a group of 87 fifth-grade students. The study used a microcomputer based drill and practice program for the experimental group. The control group participated in a non-microcomputer program which was reported to be identical to the drill and practice program used by the experimental group. The computer literacy level of the teachers was measured by the Minnesota Computer Literacy and Awareness Assessment (MCLAA) to determine if there was a differential awareness level among the teachers of the students in the control and the experimental groups. The control group and the experimental groups were in different schools; however,

the pretest results indicate that no difference existed between the two groups. The subjects were pretested on the Mathematical Section of the Metropolitan Achievement Test, Form F, the California Test of Mental Maturity, Short Form, and the MCLAA. The results of the posttest measures, on the same standardized tests, indicate some interesting instructional avenues for some instructional computing programs. No significant differences were found between the control group and the experimental group on the math achievement measure. However, a significant difference was shown between the experimental and the control group concerning the affective, and cognitive measures of computer literacy. The researchers suggest that the computer literacy of the high ability students can be significantly improved through the use of a drill and practice math program on the microcomputer. They suggest that the use of the microcomputer as an instructional tool for high ability students accomplishes math instruction achievement gains which are equal to traditional instruction. The added benefit of increasing the computer literacy or awareness and attitudinal gains is viewed as a sufficient justification for the use of microcomputer in the classroom. School district implementation of computer literacy programs may find this research valuable as a time and money savings. Apparently, applications for using the microcomputer to

provide simple drill and practice may also be able to accomplish the goal of conveying computer literacy, as measured by the MCLAA. Perhaps those school districts that are initiating computer literacy programs will find an alternative to adding another content area to the curriculum.

Summary of the Mathematics Studies:

Hart (1981) investigated the contention that learning a computer programming language is an aid to understanding school mathematics. The 24 elementary level subjects experienced 15 minutes of BASIC, once every 3 or 4 weeks. Using standardized tests, the first year subjects achievement gains were comparable to the achievement gains made by the third year subjects. The study suggests that the use of the programming language BASIC to convey the assignment of values to variables and variable manipulation is a potentially interesting area for research.

Kleiman, Humphrey, and Lindsay (1981) studied hyperactive children to compare attention span on arithmetic problems using the microcomputer versus paper and pencil. The 18 subjects ranged in age from 6 to 14 years and were attending a child development hospital clinic. The students performance on microcomputer versus paper and pencil

versions did not differ on the number correctly worked, the average time between each of the problems worked, nor on the average time to complete a problem. However, the number of problems completed and the total time on task for the microcomputer group was double that of the paper and pencil group.

Moser and Carpenter (1982) conducted a study to investigate the transition phase as four first grade children learned to express verbal problems in symbolic written form. The microcomputer was used to facilitate the process with a specially prepared program designed to permit the student to place boxes on the video display screen. In the pretest none of the subjects could correctly write "number sentences" as representations for problems; while, in the posttest measure, three of the four subjects could successfully write number sentences to solve problems.

Steele, Battista, and Krockover (1982) sought to investigate achievement in math skills among 30 high ability 5th grade students. The study used a microcomputer based drill and practice program for the experimental group. No significant differences were found between the groups on the math achievement measure. However, a significant difference was shown concerning the affective and cognitive measures of computer literacy even though computer literacy was not taught.

Music:

A recent study (**Gross and Griffin, 1982**) sought to develop and evaluate the capability of microcomputers to contribute to the learning of musical aural skills. The subjects for the study consisted of sixteen college freshman students during a five week course in ear training. Each subject was assigned to use the computer for two, twenty minute sessions, each week during the five-week pilot project. Students were allowed to sign-up for additional time as desired on a space available basis. The students were given pretests and posttests of musical abilities and an attitude survey.

The pace and difficulty level of the microcomputer programs, for the most part, are controlled by the learner. The programs cause the learner to attempt to identify the relative pitch of successive notes. One of the programs is designed by the author to play a melody for the subject which the subject transcribes by pencil and paper into music notation. After hearing the melody and correcting the transcription, the subject uses the keyboard to record the melody on the screen for comparison by the microcomputer. The correct melody and the student melody are displayed and

compared by the microcomputer program for errors. The program is designed to progress the student to through appropriate levels of difficulty which are based upon the correctness of the student melody. Other programs provide melodies and music notations for the student to correct or identify missing music notational notes.

A comparison was made of the amount of time which the subjects used the microcomputers and their musical aural skills. Significant differences in performance were identified concerning the subjects on musical intervals and on recognition of chords as a function of the interaction with the microcomputer program. Correctly transcribing melodies, scales, and progressions were not determined to be effected by the interaction with the microcomputer program. It was recognized, by the authors, that the pretest performance of the subjects on the melodies test (93%) left little room for improvement on the posttest (97%). The other test scores which were reported cluster between 48% and 63%. This serves to indicate that discrimination is possible between pretest and posttest measures. The assumption is that the test are valid and reliable. Unfortunately, the authors did not report on the ability of the tests to measure the content correctly and do so repeatedly. The attitudinal surveys suggest that positive attitudes resulted from the interaction with the

microcomputer programs. On the pretest measure, 53% of the subjects "...reported liking computers..." while 80% reported the same on the posttest.

The authors suggest that the results of the study warrant the addition of microcomputers and software for the music training program. Although the results are favorable toward the instructional use of microcomputers, the results of this study indicate only partial success. That is, only intervals and chords were identified as being significantly effected by the microcomputer interaction. The ability of the subjects to correctly reproduce scales and progressions were not affected. Further, the subjects came into the study with an ability to identify melodies. One might suggest that development and refinement might be in order before expansion of the program is commenced.

Reading:

The Haskell Indian Junior College CMI program for a reading instruction was designed to maintain student records concerning achievement, schedule assignments, schedule tests, provide access to progress reports, and handle and analyzes data (Havlicek and Coulter, 1982). Mastery testing was used to determine if the students

achieve the competence level prescribed by the objectives. Failure to achieve mastery results in "... additional assistance as prescribed by the computer." Sequencing is maintained by assuring that each student has achieved mastery prior to advancing to the next level. The CMI program was designed to be implemented in a 30 student classroom. Standard instructional materials were used to deliver the content. The CMI program generated several reports regarding student progress, "... identifying instructional needs, selecting appropriate educational experiences, and charting learner progress. The daily profile chart created by the CMI program contained an alphabetical listing of all students with their current activity progress and test results for each objective." The report provided visible feedback to all students concerning their progress student and was available at the beginning of each day. Reports were titled "Objective Grouping," "Weekly Report," and "Yearly Report." The authors reported that the most important component "... is the combination of testing with directed learning." Each student was pre-assessed for placement. The instructor acted more in the capacity of a resource person.

There were 119 subjects in the experimental group and 101 in the control group. Nelson-Denny Reading Test was used to assess reading achievement. The pretest-posttest

design using repeated measures analysis of variance revealed significant main effects for testing (pretest vs. posttest). Significant interaction effects for Vocabulary, Comprehension, and Composite scores were cited as indications of the success of the program. The researchers reported that the experimental subjects gain scores were significantly greater ($p<.01$) than the control group gain scores.

Since the experimental subjects had lower scores on the pretest measure and higher scores on the posttest measure the technique of reporting gain scores was used. The researcher did not indicate that any significant difference existed between the group scores on either the pretest or the posttest and reported that the significance of the study was that the experimental subjects "... had higher achievement gains..." It is unfortunate that the use of gain scores leaves so many unanswered questions.

A study (**Henny, 1983**) concerning reading on a computer screen investigated abilities of both college level juniors and seniors as well as elementary level sixth graders. The results for each group are reported in two separate studies. The first study identified 72 elementary education majors as subjects for which complete data could be obtained for use in the study. The study reports using the "Basic Reading Test" as revised by R.P. Carver in 1971

and converting this test for display on a minicomputer screen.

The second study used 47 students in the sixth grade from a rural community. The entire sixth grade population was randomly assigned to either a control group or an experimental group. The author reported that a special routine was written to allow the Apple II+ microcomputer to display true lower case characters. Although this information is reported, the capability of the video display monitor is not reported and no comparison of resolution between the two studies is possible.

The intent of both studies is to report the effect of relative differences in reading speed and accuracy as a function of all upper case letters and mixed upper-lower case letters. The findings are such that reporting the results together is appropriate and enlightening. Differences were found in measures of reading speed among college students but not among the elementary level students. The college students read text displayed in mixed upper-lower case faster than all upper case text. The author suggests that the college students' word recognition capabilities permit easier differentiation when using upper-lower case letters. Further, the use of syllabication and word decoding using letter-sound correspondence causes elementary level students to read the letter or letter pairs

in each word. The research indicates that adults have skills which permit a word or group of words to be read while children read letter pairs. Whether this is a developmental capability or dependent upon educational tactics remains to be discovered. The author suggests that consideration should be given to presenting upper-lower case text to elementary level students. Since the reported research indicates that word form is important to adult reading rates, introduction of mixed upper-lower case letters may enhance children's reading speeds.

On the other hand, accuracy appears to have been effected by the differential use of upper case and upper-lower case letters among the college students but not among the elementary level students. The college level students read all upper case text with greater accuracy than they read mixed upper-lower case. The author suggests that the use of all upper case letters forces the college students to attend to letter combinations rather than recognition based upon word shape.

The comments of the elementary level students indicate that the resolution of the particular video display screen used with the Apple II+ microcomputer was poor. The students were reported to have commented that the mixed upper-lower case letters were easier to read and the students were more accustomed to them; however, "...all

capital text was bigger and clearer so they could see it better." As is often the case with cheap color display monitors, "bleeding" of colors often results in poorer resolution. Unfortunately, there is no indication of the type of monitor used. Were a monitor used with the elementary level students which was equal in quality to that used with the college level students, a more accurate comparison could have been made. However, the case must be made that the type of monitors used are probably of the type used regularly in the elementary level classroom and the research should be carried out on similar equipment. The author does suggest that research should be carried out to discover "...the optimum size and style of type that will provide a clear image on the computer screen." Although the suggestion is well intended, the question of image resolution is dependent upon cost. More money will buy higher resolution; however, education is typically not funded well enough to provide the necessary equipment. Monies are appropriated to provide high resolution video display screens in many areas; but, elementary level reading programs are definitely not one of those areas.

The author adds that the design and display of instructional computing materials is often accomplished by computer specialists. Certainly, educators must take a more active role in designing and developing instructional

computing materials. But, until educators take the initiative to acquire formal training in the technical aspects of computing, it is unlikely that effective instructional computing advances will be forthcoming. It is even more unlikely that computer specialists will become sufficiently interested in education in order to become curriculum specialists for instructional computing. Finding effective educators who have the aptitude and motivation to benefit from formal, technical computer training is far more likely than finding computer specialists who have the personality characteristics and motivation to become effective K-12 classroom educators and curriculum developers.

Summary of the Reading Studies:

Havlicek and Coulter (1982) conducted a study using a CMI reading instruction program to maintain student records concerning achievement, schedule assignments, schedule tests, provide access to progress reports, handle, and analyze data. There were 119 subjects in the experimental group and 101 in the control group. The pretest-posttest design using repeated measures analysis of variance revealed significance main effects for testing (pretest vs. posttest). Significant interaction effects for Vocabulary,

Comprehension, and Composite scores were recorded. It was reported that experimental subjects gain scores were significantly greater (p<.01). Unfortunately, the use of gain scores concerning the results of this particular study make any meaningful inferences difficult.

Henney (1983) studied reading on a computer screen to investigate abilities of 72 college students and 47 elementary level sixth graders. Differences were found in measures of reading speed among college students but not among the elementary level students. The college students read text displayed in mixed upper-lower case faster than all upper case text. The college level students read all upper case text with greater accuracy than they read mixed upper-lower case. No differences in accuracy were detected among the elementary level students.

Science:

A study was conducted to discover computer literacy and science content knowledge (Anderson, Klassen, Hansen and Johnson, 1980). A randomly selected experimental group of 340 ninth and eleventh grade students were identified from a single high school. The subjects were controlled for male/female, 9th/11th, and low/high prior computer exposure

such that approximately 50% of the subjects were included in each group. The study was conducted for a period of two months in the Spring of 1979. The subjects interacted with a microcomputer instructional package concerning water pollution which had been modified for purposes of the study. The authors identify the specific programmatic alterations to which the reader might wish to refer.

An interesting thrust of this study was an attempt to investigate the relative effects of a "malfunction treatment" and "enriched display" on the cognitive performance and affect of the subject. Approximately two-thirds of the way into the lesson, a system failure was simulated. This "malfunction treatment" consisted of garbage on the screen followed by a complete simulated system lock-up. The student was left with no alternative except to request aid from the "assistants." The "assistant" pretended to briefly perform retrieval procedures on the keyboard and succeed in returning the student to the exact screen being used before the simulated system failure. The "enriched screen" consisted of a swimming fish which turned into a skeleton after the oxygen level of the water became too low. A "multicolor mosaic" was displayed for thirty seconds prior to the interaction with the pollution tutorial. Differing colors were used on

graphs which required the display of two lines simultaneously.

It was reported that the control group of 153 subjects achieved an average of 27% correct answers on the pretest measure of science content while the experimental group of 340 subjects correctly answered 70%. The researchers indicate that the difference between the control and the experimental group is significant at the $p<.01$ level of confidence. On the 6 months follow-up posttest measure, the subjects answered 51% correctly. The researchers suggest that this indicates that a relatively short 15 minute exposure to a content, via the microcomputer, can result in significant learning gains in science among ninth and eleventh grade students.

Several affective indicators were measured to discover the effects on "Awareness," "Mystique," "Enjoyment," "Anxiety," "Self-Efficacy," and "Self-Esteem." A significant reduction in computer anxiety and a significant increase in computer efficacy resulted from a comparison of the experimental and the control groups. Similar changes were observed within the experimental groups. The authors stated that the effect of the "Malfunction" and "Enriched Display" on the subject's affect must be inferred from the computer efficacy measure. The subjects which encountered the "Malfunction" were reported to be less likely to realize

an increase in their computer efficacy. The "Enriched Display" was determined to have no measured effect on the subjects.

The results of the posttest which were administered 6 months later suggest that the interaction with a computer fosters a desire in the subjects to learn more concerning computers. The authors cite evidence of this in the computer literacy scores. The only difference in computer literacy was measured on the 6 months posttest. The authors suggest that the students were motivated to investigate computers after their experience and thus, the literacy scores increased only after sufficient time had elapsed. This is further supported by the significant reduction in "Computer Mystique" on the 6 months posttest measure.

A study (**Ploeger, 1981**) was begun to develop and evlauate an interactive microcomputer program simulation concerning science classroom laboratory safety. The subjects for the study were elementary preservice teachers enrolled in the student teaching field experience program at the University of Texas at Austin. A total of 52 subjects were used during the Spring of 1981.

The Randomized Solomon Four-Group design (Campbell and Stanley, 1970) was chosen as the experimental design for this study. Each subject in the pretest group was presented with a black and white line drawing. The line drawing

depicts 14 elementary school level students in an ongoing elementary school science classroom laboratory. Each of the depicted students is identified in the drawing by a clearly lettered name on the drawing next to the student. Of the 14 depicted students, 6 were judged to require action by the teacher in order to prevent an accident from occurring. This action is required to insure that a safe environment would be maintained in the science classroom laboratory (Ploeger, 1980). Each subject was asked to view the black and white line drawing. They were then asked to identify the student in the drawing which they believed requires the most immediate teacher action. That is, the subjects were instructed to select the student depicted as being in the most dangerous situation and requiring the most immediate teacher action. The subjects were requested to use safety as the sole criteria for determining which students were to be dealt with. The subjects were requested to write the name of each student requiring a teacher action in rank order of the student requiring the most immediate teacher action to least immediate teacher action.

The subjects in the no pretest group were given a black and white line drawing depicting an adult and an elementary level child working in a kitchen. The subjects were asked to list the items in the depicted kitchen which they might

reasonably expect to find in an elementary school level science classroom laboratory.

The subjects in the treatment group were asked to interact with the computer program simulation concerning safety in the elementary level school science classroom laboratory.

The subjects in the no treatment group were asked to interact with a computer program simulation involving gaming and probability.

All subjects were given the posttest which consisted of the black and white line drawing used by the pretest group. The instructions given to the posttest subjects were the same as the instructions which were given to the pretest subjects.

The results of this study suggest that a microcomputer program simulation is effective in enhancing the ability of preservice teachers to recognize and correctly handle hazardous situations in the science classroom laboratory. Differences between the experimental and control groups were determined to be highly significant ($p<.001$). The results suggest that preservice teachers were relatively unable to identify and prioritize safety hazards in the science classroom laboratory prior to interaction with the computer program simulation. It is believed that by interacting with the computer program simulation, preservice teachers can

learn to recognize safety hazards in the real classroom. Since the computer program simulation is relatively inexpensive and free from danger, it is believed to be a viable teaching tool.

The purpose of another study by this researcher (Ploeger, 1982) was to investigate the effectiveness of color line drawing visuals as compared to black and white line drawing visuals when used with a computer program simulation concerning safety in the science classroom laboratory.

The Randomized Solomon Four-Group design (Campbell and Stanley, 1970) was chosen for use in this study. The subjects for this study include preservice science teachers enrolled in the student teaching field experience program at The University of Texas at Austin. Also, inservice science teachers enrolled in a continuing education program at Houston Community College were used as subjects. A total of 48 subjects were used for the study.

Each of the subjects in the study was presented with a line drawing. The line drawing depicts 14 elementary level school students in an ongoing elementary school science classroom laboratory. Each of the depicted students is identified in the drawing by a clearly lettered name on the drawing next to the student. Of the 14 depicted students, 6 were judged to require action by the teacher in order to

prevent an accident from occurring in the science classroom laboratory (Ploeger, 1980). Each subject was asked to view the line drawing. The subjects were instructed to select the student depicted as being in the most dangerous situation and requiring the most immediate teacher action. They were requested to use safety as the sole criteria for determining which students were to be dealt with. Each subject was requested to write the name of each student requiring a teacher action in rank order of the student requiring the most immediate teacher action to least immediate teacher action. The subjects in the experimental group for the study were each given a color line drawing of the depicted science classroom laboratory. The control group used an identical drawing in black and white.

The microcomputer program simulation is designed to evaluate the relative danger of the situation. If no more dangerous situation exists, the subject is allowed to continue interacting with the student which they have chosen until the hazardous situation has been resolved. The subject must correctly identify each depicted safety hazard in the line drawing. All safety hazards must be dealt with before the subject is allowed to end the microcomputer program simulation.

The data suggest that there are no significant differences between the groups in the study. The data

analysis indicates that one may infer that the subjects using the Color visual and the subjects using the Black & White visual performed equally well on the Posttest measure. Because of the experimental design, if may be inferred that the Pretest experience had no effect on the Posttest performance of the subjects.

There is a tendency for educational microcomputer programs to attempt to use color visuals in the belief that, in some way, color enhances the ability of the learner to learn. This study lends support to the research studies which suggest that the use of color visuals has little effect on the performance of subjects when used with an interactive microcomputer program simulation. The study supports the research that indicates that only essential details in visual representations are necessary in order to facilitate learning. Based upon the results of the study, it is suggested that the use of color visuals provide no additional clarification as compared to black and white visuals when used with a microcomputer program simulation. Given the fact that color visuals may be more costly to produce, the study suggests that considerable savings may be realized in those instances in which color visuals are not demonstrated to clearly provide essential detail that are not available with black and white visuals.

A study was completed (Soldan, 1982) in which the goal was to evaluate microcomputer part of the courseware developed by the SUMIT Courseware Development Project. Computer aided instruction (CAI) modules were developed, as part of the project, for use on a microcomputer, entitled "Population Growth," "Predator Prey," and "Mitosis/Meiosis." Subjects from the biology classes at Michigan Technological University were used in the experiment. The numbers of subjects in each of the experimental and control groups varied for each of the instructional modules. The researcher reports that each of the subjects were tested in a pretest posttest study using the same 5 to 9 multiple choice tests for all testings. The subjects were queried, following the posttest, to determine whether they had used the microcomputer program. The researcher could detect no difference between the posttest scores of the experimental and the control groups. A significant difference was found between the pretest scores and the posttest scores. The author concludes that learning had occurred but that the learning could not be attributed to the CAI modules. Although the study is a worthy attempt to determine the effectiveness of microcomputers in the classroom, the threats to validity completely undermine this study. No attempts were made, other than self report, to control subjects use of the microcomputer, and since the subjects

decided for themselves, no randomization of the control and experimental groups was made. The control group and the experimental group intermingled throughout the study, thus there was no control for the sharing of information between subjects.

In a study (Spain, 1982) which was nearly identical to the Soldan (1982) study, achievement scores were used to evaluate written instruction, lecture instruction, and microcomputer instruction. A variety of numbers of subjects were used (15 to 81) in evaluating the achievement of college biology students on nine microcomputer instruction modules. The researcher reports that this study used the microcomputer to administer the pretest, microcomputer module, and posttest, thus controlling for the error in allowing the subjects to self report as to the use of the microcomputer program module. The author reports that all subjects realized a significant gain on the posttest score over the pretest score. However, a "Special split-section" was used in attempt to discover relative differences between alternative instructional strategies. The results of this effort are reported to indicate that achievement was significantly higher for microcomputer only instruction than it was for written material only instruction. The achievement of the students using the microcomputer only instruction did not differ significantly from the lecture

only instruction. The implication is that effective microcomputer software is, at least, as effective as traditional lecture methods but far superior to textual materials. As with many other studies, there is no way of knowing the appropriateness of the instructional use of the microcomputer or any other of the instructional tactics. However, it could be argued that lecture and textual materials have been subjected to a significant number evaluative revisions while the microcomputer materials have only begun to be recognized as potentially valuable instructionally.

A meta-analysis study (Wise and Okey, 1983) sought to investigate the effect of instructional microcomputing on the achievement of students in science. The paper outlines the goal of the research study and identifies areas in which the authors suggest that further research are needed. The authors restricted the scope of the research to the well known data bases for education and research: Resources in Education (RIE) and Current Index of Journals in Education (CIJE). The timeliness of publications included in the study was insured by restricting the publication dates to between January 1979 and June 1982. The descriptor title of "microcomputer" and "computer-assisted instruction" were included in the study. The authors report that "Nearly one thousand titles were examined." Of the many studies

included in the search, the authors included twelve studies in the meta-analysis from which thirty-one student outcomes were identified and coded. From the student outcomes, only ten effect sizes were obtained which resulted in a mean effect size of +.82. That is, on the average (mean), a study using microcomputers was found to effect student achievement by 82 percentile points. However, the authors stated in the presentation of the paper that one of the studies had reported a very large effect on the subjects. By removing this study from the meta-analysis, the mean effect size of the remaining eleven studies was reduced to +.38. It is interesting to note that a mean effect size of this magnitude is more in line with other meta-analysis studies in the literature. Since the effect of outliers on research is well known and documented, one is well advised to accept the more conservative mean effect size value. It is suggested by this and other research that there is general positive effect upon student achievement which is attributable to instructional microcomputing.

The authors state that eight of the studies used subjects which were of college level, two studies were completed with high school level subjects, one study used middle school subjects and one study used pre-school subjects. Several modes of instruction were used, such as, drill and practice, tutorial, problem solving and others.

The authors make a number of suggestions which go beyond the findings of the study; however, the general findings of the study suggest that the research base supporting the use of instructional microcomputing in science education is growing.

Middle school level subjects were used in a pretest-posttest measure of both attitude and achievement concerning the use of a microprocessor driven energy simulator (Zielinski, 1981). The 104 subjects were in eight classes and had an average age of 14 years. The subjects participated in a 10 day unit involving energy concepts. The experimental group had a single 55 minute experience on the simulator on the last day of the unit. The simulator consists of a central control unit and four hardwired, attached input units. The input units contain switches which allow groups of students to make changes in certain environmental parameters from a distance of about 25 feet away from the central control unit. The central control unit coordinates the various changes in environmental requirements made from all of the input units. The control unit displays the status of the world environmental conditions based upon the various requirements. The environmental simulator is intended to allow students to observe the quality of life based upon world reserves of natural resources and resource use rates.

This study attempted to measure achievement and attitudinal changes as a result of a short interaction with the environmental simulator. The author developed an attitudinal measure which was determined to be quite reliable (pretest .79, posttest .86). The study reports that no significant differences were found between the experimental and the control groups on either the pretest or the posttest. One might conclude from this study that the environmental simulator fails to have a measurable effect on the subjects. However, the author suggests that the short duration of the subject's exposure to the environmental simulator may be the source of the inability to detect a change in attitude or achievement. Based upon subjective response to the environmental simulator, further research concerning the effectiveness of the simulator most certainly will be a fruitful avenue.

Summary of the Science Studies:

Anderson, Klassen, Hansen and Johnson (1980) sought to measure computer content knowledge using science as a content area among a group of 340 ninth and eleventh grade students. An interesting thrust of this study was an attempt to investigate the relative effects of a "malfunction treatment" and "enriched display" on the

cognitive performance and affect of the subject. The researchers suggest that a 15 minute exposure to a content, via the microcomputer, can result in significant learning gains in science. The results of the posttest which were administered 6 months later suggest that the interaction with a computer fosters a desire in the subjects to learn more concerning microcomputers.

Ploeger (1981) completed a study to develop and evlauate an interactive microcomputer program simulation concerning science classroom laboratory safety. A total of 52 subjects were used in a Randomized Solomon Four-Group design. Each subject in the pretest group was presented with a black and white line drawing. The line drawing depicts 14 elementary school level students in an ongoing elementary school science classroom laboratory. Each subject was instructed to select the student depicted in the line drawing as being in the most dangerous situation and requiring the most immediate teacher action. The results of this study suggest that a microcomputer program simulation is effective in enhancing the ability of preservice teachers to recognize and correctly handle hazardous situations in the science classroom laboratory.

Ploeger (1982) conducted another study investigate the effectiveness of color line drawing visuals as compared to black and white line drawing visuals when used with a

microcomputer program simulation concerning safety in the science classroom laboratory. A total of 48 subjects were used in a Randomized Solomon Four-Group design for the study. The subjects in the experimental group for the study were each given a color line drawing of the depicted science classroom laboratory. The control group used an identical drawing in black and white. The microcomputer program simulation is designed to evaluate the relative danger of the situation. The data analysis indicates that the subjects using the Color visual and the subjects using the Black & White visual performed equally well on the Posttest measure. It is also inferred that the Pretest experience had no effect on the Posttest performance of the subjects.

Soldan (1982) completed a study using university students to evaluate the microcomputer part of the courseware developed by the SUMIT Courseware Development Project. The researcher could detect no difference between the posttest scores of the experimental and the control groups. A significant difference was found between the pretest scores and the posttest scores. The author concludes that learning had occurred but that the learning could not be attributed to the CAI modules.

Spain (1982) studied achievement scores to evaluate written instruction, lecture instruction, and microcomputer instruction on a variety of numbers of college biology

subjects (15 to 81). The findings indicate that effective microcomputer software is, at least, as effective as traditional lecture methods but far superior to textual materials.

Wise and Okey (1983) conducted a meta-analysis study to investigate the effect of instructional microcomputing on the achievement of students in science. Several modes of instruction were used, such as, drill and practice, tutorial, problem solving and others. The general findings of the study suggest that the research base supporting the use of instructional microcomputing in science education is growing.

..elinski (1981) used 104 middle school level subjects in a pretest-posttest measure of both attitude and achievement concerning the use of a microprocessor driven energy simulator. The subjects participated in a 10 day unit involving energy concepts. The experimental group had a single 55 minute experience on the simulator on the last day of the unit. The study reports that no significant differences were found between the experimental and the control groups on either the pretest or the posttest.

Typing:

The stated purpose of this study is to compare the relative efficacy of two typewriting skill teaching methods (Lindsay, 1982). This study identifies four specific areas of measurable achievement concerning typewriting instruction: touch typing and machine operation, word division and punctuation, copy speed and accuracy, and production ability. Of the four, only straight copy speed and accuracy is investigated in this study. The sample for the study is comprised of 105 students in typing classes in the Eric Hamber Secondary School, Vancouver, British Colombia. The subjects were randomly assigned to an experimental and a control group for purposes of inclusion in the non-equivalent control group design. The author suggests that common threats to validity are avoided by this design and that the Hawthorne effect is minimized by the four week treatment period.

The experimental group used a microcomputer program designed to provide typing experience in an instructional computing environment on a Commodore microcomputer. The microcomputer typing program used in this study provided for the student to interact with the machine in three distinct modes. The Mode 1 provides for drill and practice with pretest, practice, and posttest feedback sessions as well as speed and error diagnostics. Mode 2 is a line-by-line typing practice which provides specific keystroke repetition

in the context of a single line of text which may be repeated. Mode 3 provides for the student to type externally generated paragraphs and receive feedback concerning typing speed which is based on 40 characters per line rather than the actual number of characters in the text. The control group was reported to have used the same procedures and text as the experimental group except for three variations. The control group typed on IBM electric typewriters, used text materials which were printed on paper, and had to calculate their own speed and accuracy scores.

Differences in keyboards, placement of critical control keys, and slow tape load rates were cited as problems. However, eye appeal, reduction of eye strain, and dependability of equipment were identified as positive features. The teachers were reported to have positive attitudes toward the microcomputers concerning features such as flexibility, freedom to enhance reinforcers, and increased motivation. The study concluded that the use of a microcomputer is as effective at teaching straight copy speed and accuracy as is the use of an electric typewriter. This finding is independent of age, sex, and class assignment within the constraints of this study. It was reported that two males in the study did not achieve

accuracy levels equivalent to their control group counterparts.

CONCLUSIONS

This brief work, The Effectiveness of Microcomputers in Education, is designed to provide access to research in the field of instructional microcomputing in a manner which is understandable. The research which has been included is believed to be well done, timely and of significance value to those interested in instructional microcomputing. The survey studies have been reported in order to provide a framework from which to view the research. It is believed that appropriate application of research serves to enhance effective educational strategies.

The research has clearly demonstrated that instructional microcomputing can be a valuable educational tool. The studies support the belief that affective measures such as motivation and self-esteem are enhanced as a result of the inclusion of microcomputers in an instructional setting. Time-on-task may be expected to increase and problem solving strategies may be altered among students. The BASIC programming language was demonstrated to improve math skills while the use of LOGO neither supported increasing math skills nor formal reasoning skills. Interestingly, computer literacy may be improved

simply by encouraging student use of microcomputer. Computer literacy need not be taught as a separate content.

The use of instructional microcomputing has been demonstrated to be most effective as an adjunct to normal or traditional instructional tactics. Instruction has been demonstrated to be most effective when instructional objectives are clearly identified and appropriate for the learner. As with any instructional methodology, inappropriate application of any tactic seldom provides satisfactory results.

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